





# Cis-lunar Working Group Report

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























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## Cis-Lunar Working Group

### Part of the Next Generation Exploration Conference

### Declaration

*Space agencies are committed to the “safe, sustained, affordable human and robotic exploration of the Moon, Mars, and beyond.” However, we recommend that they explicitly define our ultimate goal and motivation in order to portray a sense of purpose to the public. Our goal is sustainable human settlement of the Moon and Mars and our motivation is to preserve the human race. All secondary exploration and science objectives flow from this main goal and are still imperative to our success. As an economic guiding principle, governments should be limited to those areas where only government can perform the activity and should recognize and coordinate with the larger private and military sectors. Also, space agencies must continue to fund the interdisciplinary science necessary to characterize environmental hazards associated with dust, radiation, surface charging, topology, and meteorites in order to make our first attempts at extraterrestrial living viable.*

#### 1.0 Introduction

#### 2.0 Themes

- 2.1 Prepare for future human and robotic missions to Mars and other destinations.
- 2.2 Pursue Scientifically-driven Activities
- 2.3 Extend Human Presence to the Moon to Prepare for Settlement
- 2.4 Expand Earth’s Economic Sphere to Encompass the Moon
- 2.5 Strengthen existing and create new global partnerships
- 2.6 Engage, Inspire, and Allow the Public to Participate in Space Exploration

#### 3.0 Objectives

- 3.1 Settlement
- 3.2 Expanding the economic sphere

#### 4.0 Key Recommendations

- 4.1 Lunar Exploration Program for the Survival of Humanity
- 4.2 Fund Interdisciplinary Lunar Science
- 4.3 Focus more on Global Partnerships
- 4.4 Focus on Areas Where Government is Needed the Most

#### 5. A Potential Future for Lunar Settlement

- Phase I: The assessment period
- Phase II: The adaptation period
- Phase III: Expansion period

#### Conclusion

#### 1.0 Introduction

The Cis-Lunar working group defined its charter to be the Earth-Moon system, including the activities conducted off-Earth and on the Moon. The Exploration Systems Mission Directorate (ESMD) within NASA, and possibly and other space agencies, are committed to the “safe, sustained, affordable human and robotic exploration of the Moon, Mars, and beyond.” We encourage governments to explicitly define the ultimate goal and motivation in order to portray a sense of purpose to the general public. Our ultimate goal is human settlement beyond Earth; our motivation is to ensure human survival.

This task is beyond the remit of space agencies and thus the private sector should be engaged, and exploration of possible forms of inclusions/cooperation should be prioritized. The ultimate goal of settlement and intermediate goal of exploration are enabled by including other actors such as the private sector in co-developing and co-maintaining a Cis-Lunar infrastructure.

This chapter outlines the themes for Cis-Lunar exploration, and explores the symbiotic relationship between the goal of settlement and commerce in the objectives section. Further, we outline four specific recommendations then describe in detail a potential future for a permanent human presence on the Moon extending the civilization off-Earth.

## **2.0 Themes**

This section outlines the proposed changes and additions to the exploration themes modeled after the draft version of the interim lunar exploration strategy provided to NGECC for comment.

### *2.1 Prepare for future human and robotic missions to Mars and other destinations.*

Reduce the risks and increase the productivity of future missions in our solar system by testing technologies, systems, and operations in an off-Earth planetary environment. Using the Moon as a test-bed for Mars will help us learn how to explore. The initial settlement of the Moon will provide technology for future exploration and a template for future settlements.

### *2.2 Pursue Scientifically-driven Activities*

Engage in scientific investigations to address fundamental questions about the solar system, the universe and our place in them by:

- *Of the Moon:* Study the history of the Moon and the current lunar environment and structure to learn about the evolution of our solar system;
- *On the Moon:* Understand the effects of the lunar environment on terrestrial life and the equipment that supports lunar inhabitants;
- *From the Moon:* Use the Moon as a platform for performing scientific investigations that are uniquely enabled by being on the lunar surface, including observations of the Earth and other celestial phenomena.

### *2.3 Extend Human Presence to the Moon to Prepare for Settlement*

Develop the knowledge, capabilities, and infrastructure required to live and work on the Moon, with a focus on sustainable growth of:

- The duration of time that individuals can live safely on the Moon;
- The number of individuals that can be supported on the Moon;
- The level of self-sufficiency of operations on the Moon;
- The characterization, utilization, and commercialization of lunar resources;
- The degree of non-governmental activity.

The long-term survival of the human species will be greatly increased by backing up the biosphere with permanent settlements on the Moon and other locations. This will help to reduce the probability of the demise of human civilization due to a catastrophic event such as the impact of a large asteroid, nuclear war, climate change, or biological weapons.

#### *2.4 Expand Earth's Economic Sphere to Encompass the Moon*

Create new markets, based on lunar and Cis-Lunar activity that will return economic, technological, and quality-of-life benefits to all humankind.

1. Involve private and commercial interests to the maximum extent possible; initially by purchasing services (transportation, propellants, etc), and eventually transitioning operations of infrastructure to private parties.

2. Sustain a human presence beyond Low Earth Orbit by mobilizing resources through a working public-private mix of space investments into Cis-Lunar infrastructure and resource utilization leading to economic return (in the broadest sense) and reinvestment.

#### *2.5 Strengthen existing and create new global partnerships*

Enhance global security by increasing international cooperation via transparent activities of space agencies and shared responsibility and redundancy of space exploration activities.

#### *2.6 Engage, Inspire, and Allow the Public to Participate in Space Exploration*

Use a vibrant exploration program to inspire the public through outstanding human achievement. Excite the public about space exploration while educating them about the benefits of exploration. Encourage students to pursue careers in high technology fields, and ensure that individuals enter the workforce with the requisite scientific and technical knowledge and enthusiasm necessary to sustain exploration. Make space more relevant to the lives of people today by creating meaningful science and exploration activities for the public to participate in global exploration activities.

### **3.0 Objectives**

As a result of our discussion, we recommend that the following two objectives have more emphasis: the first focusing on settlement, and the second expanding the economic sphere. These objectives should be thought of as a reinforcing system as both are enablers of the other.

#### *3.1 Settlement*

While the meaning of our existence in the universe is debated, the need to protect it is not. As long as humans remain confined to a single planet, there is a possibility that a catastrophic event could end civilization. Such events include a global disease pandemic, asteroid or comet impact, and nuclear war, among others. Extending human civilization to space could enable our species to avoid certain such disasters and thus increase the probability of survival. The long-term survival of the human species will be greatly increased by backing up the biosphere with permanent settlements on the moon and other locations.

#### *3.2 Expanding the Economic Sphere*

With agency budgets fixed over the coming decade, in order to enable space agencies to focus their efforts on science and exploration, and to mobilize more resources for the Lunar Exploration Program, the private sector should play a larger role and be incorporated early on in the definition of the program. This means new forms of public/private relationships need to be stimulated. In addition, as an enabler of permanent settlement on the Lunar surface, a legacy of the Lunar Exploration Program could be new commercial opportunities

and new economies coming the infrastructure and proof of principle of space commerce demonstrated by our envisioned Lunar Exploration Program, based on exploitation of Cis-Lunar resources.

Thus, we recommend greater focus on the role of the private sector in the Program, not only for enabling the program itself, but in view of the legacy of the program, to go beyond planting flags but to stimulate a sustainable human presence in Cis-Lunar space with the possibility of new economies (based on space resource exploitation) with wealth creation feeding back to Earth but also providing a platform for venturing further into the solar system, not only technological capability but a proof of viability of space commerce and resource exploitation beyond LEO.

## **4.0 Key Recommendations**

### *4.1 Lunar Exploration Program for the Survival of Humanity*

Survival of humanity needs to be explicitly stated as reason for settlement in “settlement theme” and as overarching reason for “Why are we going to the moon?” Settlement, or the evolution of human civilization, dictates the evolution of the program at the beginning and enables all other objectives.

### *4.2 Fund Interdisciplinary Lunar Science*

To achieve sustainable Space Exploration, government sponsored space agencies should fund cross-interdisciplinary (CID) science. This is particularly important for scientific investigations of the lunar dust, and other aspects of the lunar environment, to understand the effects of the lunar environment on terrestrial life and the equipment that supports lunar inhabitants. In addition, funding opportunities for lunar science should be similar to the Mars program. Governments should be funding low Technology Readiness Level projects to help advance them to flight capability. Explore the use of the Moon as a platform for performing scientific investigations that are uniquely enabled by being on the lunar surface, including observations of the Earth and other celestial phenomena.

### *4.3 Focus more on Global Partnerships*

Space agencies and companies should promote international exchange of staff. Similar to the scientific communities’ ability to transcend boundaries for the pursuit of knowledge, explorers would be greatly enabled by diminishing national laws that prohibit the coordination and exchange of needed information. Furthermore, complementary but independent missions will yield significant scientific discoveries while minimizing risk on the critical path.

### *4.4 Focus on Areas Where Government is Needed the Most*

The role of publicly funded organizations must shift and focus on specific areas of the Lunar Exploration Program, rather than trying to do everything themselves. Agencies should recognize capabilities of private industry, and transfer as many tasks as possible / feasible from agency to industry. This could encourage / stimulate the growth of new industries and markets and transition what would previously be government constructed and run facilities into the private domain. This evolution will ensure evolving exploration goals, as agencies focus efforts on science and exploration.



## 5.0 A Potential Future for Lunar Settlement

Human presence on the moon could be divided into three phases of evolution. In Phase I, humans reach the moon and are supported by the resources they carry from Earth. This is the *assessment period*, where the target locations for sustained human presence are identified, temporary habitats are built, and the requirements surviving on the moon autonomously are determined. In Phase II human existence on the moon becomes self-sustaining. This is the *adaptation period*, where all critical systems become fully sustainable using only resources and infrastructure currently available on the moon. In Phase III, the technology for developing duplicate lunar bases is created. This is the *expansion period*, where re-habitation is possible without support from the Earth.

	2006	2010	2018	2022	2027	2037	2045 →
Pre-Human	Orbiters						
	site selection						
		landers/rovers					
		environmental characterization					
		engineering demonstration					
Phase I			*First Manned Landing				
			Sortie Missions- Phase I				
			Development- Phase I				
				Production- Phase I			
Phase II					Operation- Phase I		
					Development- Phase II		
						Production- Phase II	
Phase III							Phase III Begins →

### Phase I: The Assessment Period

(weeks – months, 2 – 5 people):

1. Installation of a temporary lunar communication network
2. Rover-based site selection
  - a. Environmental characteristics
    - i. ground bearing strength
    - ii. regolith resources
    - iii. radiation
    - iv. solar energy
    - v. landing obstacles
  - b. Power options
  - c. Communication options
  - d. Mobility limitations
  - e. Scientific objectives
3. Installation of an initial habitat
  - a. Combination of in-situ and earth resources
  - b. Considering the essential elements
    - i. Oxygen

- ii. Water
- iii. Food
- iv. Energy
- v. Communication
- 4. Rover based surface exploration
- 5. Implementation of short-term science objectives
- 6. Demonstration of future technologies
  - a. Dust mitigation systems
  - b. All-terrain rovers
  - c. Regolith processing systems
  - d. Radiation shielding systems

### *Phase II: The Adaptation Period*

(0-10 years, 2 – 10 people):

- 1. Establish in-situ resource utilization systems
  - a. Oxygen
  - b. Water
  - c. ...
- 2. Making the lunar communication network more robust
- 3. Establish a persistent energy source
- 4. Development of a lunar “green house”
- 5. Development of a lunar medical care facility
- 6. Development of systems maintenance tools
- 7. Development of a “last resort” system for returning to Earth

### *Phase III: Expansion Period*

(permanent, 10 – 100 people):

- 1. Base replication
- 2. Space exploration from moon

## **Conclusion**

We encourage governments to explicitly define the ultimate goal and motivation in order to portray a sense of purpose to the general public. Our ultimate goal is human settlement beyond Earth; our motivation is to ensure human survival. This task is beyond the remit of space agencies and thus the private sector should be engaged, and exploration of possible forms of inclusions/cooperation should be prioritized. The ultimate goal of settlement and intermediate goal of exploration are enabled by including other actors such as the private sector in co-developing and co-maintaining a Cis-Lunar infrastructure.

Public participation (rather than outreach) is important for success. Thus interaction fora such as public debate and consensus conferences, ‘public participation’ (the participation of the public directly in missions), as well as more standard outreach mechanisms should be invested in and framed as a core activity.

# Cis-lunar

Everything within the  
Earth-Moon system

## Core themes

- Environmental Characterization
- Policy & Outreach
- Settlement
- Economic & Commerce



## EXPLORATION SYSTEMS MISSION DIRECTORATE

*Safe, sustained, affordable human and robotic  
exploration of the Moon, Mars, and beyond...*

To achieve this vision for space exploration,  
NASA must fund cross-interdisciplinary (CID)  
science...

### Environmental Hazards:

- -Dust
- -Radiation
- -Surface Charging
- -Topology
- -Macro-meteorites

### CID Science:

- Biology
- Materials
- Electronics
- Heliophysics
- Geology

## Science recommendations

- **funding** opportunities for lunar science should be similar to the Mars program.
  - Perhaps a common planetary funding system
  - Shouldn't be Mars vs everything else
- government should **fund** low TRL
  - Advance it to flight levels
  - Who else but government can fund this?

## Outreach recommendations

- Identify technology transferred to daily life.
- Scientists & Engineers involved in public outreach
  - Partner with student internships, volunteer organizations, etc
- Educate media correspondents so they can accurately report on space
- Use new media outlets that showcase spaceflight:
  - YouTube, Podcasts, Astronaut blog
  - show the human side!
  - Annual “State of Space” DVD

## Global Partnerships

- Promote international exchange of staff
  - similar to current scientific collaborations
  - eliminating or severely reducing ITAR restrictions
- Complementary but independent missions
  - provide significant scientific yield
  - with minimal risk to fellow partners (no weak link)

## Economic Guiding Principles

- Government role must be limited to only those areas where there is irrefutable demonstration that only government can perform activity
- Implement and recognize larger private industry
- Specific goals:
  - industry to have primary role of providing services
  - foster new markets and commercial opportunities

## Economic Theme Revisions

- Expand Earth's economic sphere to encompass the Moon
  - Pursue lunar activities with direct benefits to life on Earth.
- Involve private interests to the maximum extent possible
- Government to purchase services initially
- Transition operation of gov facilities to private interests
- Ensures evolving exploration goals

## Spreadsheet Revisions

- Greater outsourcing of required cis-lunar capabilities
  - Transportation
  - Power
  - Habitation
  - Research
- Encourage growth of new industry and markets
- Protect IP for researchers on government lunar facilities

## Settlement

- Themes Document *Lacks description of WHY*
  - Reason for settlement is the long-term survival of the human species...
- To accomplish settlement, make it the primary requirement!
  - Dictates evolution of program from beginning
  - Enables all other objectives

# Settlement Phases

Phase I: Sorties	Phase II: Self-Sustainability	Phase III: Expansion
Installation of temporary communication network	Persistent, reliable power source	Ability to create new bases on moon
Rover based site selection	Ability to grow and process food, and extract water, and oxygen	Permanent settlement
Installation of initial habitat	Installation of permanent communications network	Lunar based solar-system exploration
Rover-based surface exploration	Ability to service and maintain all equipment	